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30 April 1968

Materiel Test Procedure 6-2-200  
Electronic Proving Ground

U. S. ARMY TEST AND EVALUATION COMMAND  
COMMODITY ENGINEERING TEST PROCEDURE

TDM-PCM MULTIPLEXERS

1. OBJECTIVE

The objective of this Materiel Test Procedure (MTP) is to describe a procedure for determining the technical performance characteristics of multiplexing equipments employing time-division multiplexing (TDM) with pulse-code-modulation (PCM) principles and techniques.

2. BACKGROUND

In the field of electrical communications "multiplexing" is the process of transmitting several individual messages or signals over a common path or circuit without mutual interference. There are two basic types of multiplexing in current use, frequency-division-multiplexing (FDM) and time-division-multiplexing (TDM), each requiring some form of signal conversion or modulation.

In frequency-division-multiplexing a definite, relatively broad frequency band is divided into a number of narrower bands, each modulated by the signals of an individual message circuit or voice channel. In general, a wire, cable, or radio system provides for transmission of the total frequency band containing the combined channel signals. At the opposite system terminal the total band is subdivided (demodulated) into the original narrow bands or channels each carrying its original, individual intelligence.

In time-division-multiplexing successive intervals of time are assigned to the different input channels. The analog (audio) signals of each channel are sequentially sampled at the assigned time interval of the channel. At each sampling, a pulse or a group of pulses is created that represents the amplitude of the sampled signal at that moment. Thus, bits of information from all channel signals are transmitted in rotation as one chain of pulses. At the receiving terminal, the pulses (or groups of pulses) are sorted out according to their time of arrival and diverted to their respective channel decoders where they are reconstituted to the original signal form carrying the original intelligence. (For full explanation see Appendix A).

The economic and technical advantages of PCM-TDM over other multiplex types and general acceptance of PCM-TDM in commercial and military circles establish the need for basically uniform engineering test procedures which will also allow for future conceptual variations and refinements dictated by technological advances.

3. REQUIRED EQUIPMENT

NOTE: The items listed herein are the minimum required for the performance of tests covered by this MTP. Additional items may be required to meet special test requirements.

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a. Electrical/Electronic Test Equipment

- 1) Signal/function generators
- 2) Noise generator
- 3) Frequency meter/electronic counter
- 4) Wave analyzer
- 5) Noise measuring set
- 6) Transmission measuring set
- 7) Distortion analyzer
- 8) Voltmeter, AC, with db scale
- 9) Multimeter
- 10) Oscilloscope, dual, w/camera
- 11) Special test set(s) (Designed for use with but not integral to the test item, e.g. Telephone Test Set TS-1323 (-)/PT or AN/PTM-7, RF field intensity measuring system).

b. Ancillary Systems/Equipments

- 1) Compatible Radio Relay and Tropo-Scatte sets/systems (AN/GRC-50, -66, -103, -144, or AN/TRC-112)
- 2) Compatible Cable System (May be part of test item or designed for a specific test item)
- 3) Power Equipment (Patch panel assemblies and interconnecting wire and cables)
- 4) End Instruments (Telephones, Teletypewriters, facsimile sets, data equipment)
- 5) Recorder Reproducer Equipment (Voice-frequency tape type)
- 6) Converters (Signalling and 2-wire/4-wire)

c. Facilities

- 1) Electronic-Type laboratory facility, preferable with adjacent open area.
- 2) Outdoor areas and/or sites suitable for cable installation and establishment of radio links and for conduct of electromagnetic interference tests.

4.

REFERENCES

- A. MIL-STD-188(-), Military Communication System Technical Standards.
- B. MIL-STD-461(-), Electromagnetic Interference Characteristics, Requirements for Equipment.
- C. MIL-STD, 462(-), Electromagnetic Interference Characteristics, Measurement of.
- D. MIL-STD-463(-), Electromagnetic Interference Technology-Definitions and System of Units.
- E. TM 11-486, Electrical Communication Systems Engineering.
- F. FM 11-487H-1, Electronic Test Equipment.
- G. TM 11-5805-367-12, Multiplexers TD-202/U, TD-203/U, TD-204/U, TD-352/U, TD-353/U, Pulse Form Restorer, TD-206/G, and Converter,

- Telephone Signal CV-1548/G.
- H. USAEPG Report, ETA-128, "Integrated Engineering/Service Test of Medium Capacity PCM Radio Relay and Cable System and Multiplexer Sets AN/TCC-44 and AN/TCC-45", October 1963.
  - I. USAEPG Report, ETA-144, "Integrated Engineering/Service Test of High Capacity PCM Radio Relay and Cable System and Multiplexer Sets AN/TCC-46 and AN/TCC-47", November 1963.
  - J. USAEPG Report, ETA-FR-193, "Integrated and Engineering/Service Test of AN/TRC-108, -109, -110, and -117 and AN/TCC-60 and AN/TCC-61", March 1966.
  - K. Transmission Systems for Communications, Bell Telephone Laboratories, Inc., third edition, 1964.
  - L. Multiplexing Guidelines and Standards for Interior Avionics Systems, AD 809 854, December 1966, Radio Corporation of America, DEP for ONR, Washington, D. C.
  - M. Applicable Technical Characteristics.
  - N. Applicable Qualitative Materiel Requirements.
  - O. MTP 6-2-080, Facsimile Sets.

## 5. SCOPE

### 5.1 SUMMARY

The tests described in the following paragraphs are required to determine and evaluate the technical performance characteristics of TDM-PCM multiplexing equipment and their performance in typical communication system applications.

#### 5.1.1 Parameter Tests

The objective of the parameter tests is to establish reference test data for the test item for similar tests when performed in the real system application. Specific subtests included in this category are listed below:

- a. Frequency Response - The objective of this subtest is to determine the frequency response of the test item.
- b. Input-Output Linearity - The objective of this subtest is to determine the output linearity of the test item with respect to frequency and signal level (dbmO).
- c. Gain Stability - The objective of this subtest is to determine the gain stability of the initial channel output level with a given test tone input.
- d. Distortion (Harmonic & Quantization) - The objective of this subtest is to determine the distortion level present at the output channel of the test item under given or specified input conditions.
- e. Delay Distortion - The objective of this subtest is to determine the delay distortion present with the test item in system configurations employing the "loop-back" technique (Multiplex terminals at the same location).
- f. Noise - The objective of this subtest is to determine the noise level of the output signal of the test item.

g. Crosstalk - The objective of this subtest is to determine the level of adjacent channel and intergroup crosstalk present in the test item for both directions of transmission.

#### 5.1.2 Transmission/Traffic Tests

The objective of the transmission/traffic tests are to measure the capability of the test item channels to transmit and faithfully reproduce the various message signal forms generated by communication end instruments; to measure message degradation caused by system loading (message fidelity versus number of channels in use); and to measure channel noise and crosstalk generated by various degrees of system loading. Specific subtests include:

a. Voice Transmission - The objective of this subtest is to determine the quality of output articulation of the test item for voice transmissions under varying degrees of channel occupancy and for both directions of transmission.

b. Teletype Transmission - The objective of this subtest is to determine the quality of output reproductions of the test item for teletype transmissions under varying degrees of channel occupancy and for both directions of transmission.

c. Facsimile Transmission - The objective of this subtest is to determine the quality of facsimile transmission output of the test item under varying degrees of channel occupancy and channel loading because of continuous facsimile signal transmission.

d. Noise and Crosstalk versus System Loading - The objective of this subtest is to determine the noise level of the output signal and the level of adjacent channel and intergroup crosstalk present in the test item under varying degrees of channel occupancy or loading.

e. Data Transmission - The objective of this subtest is to determine the ability of the test item to transmit and reproduce digital data under varying conditions of channel occupancy.

#### 5.1.3 Ancillary Tests

The objective of the ancillary tests is to determine adequacy and reliability characteristics of subordinate multiplexing equipment. Specific subtests include:

a. Order Wire Operation - The objective of this subtest is to determine the adequacy of communications between all attended stations of a system comprised of any combination of radio and cable links.

b. Integral Test Facilities - The objective of this subtest is to determine the adequacy and reliability of integral test facilities including alarm and fault location features.

c. Electromagnetic Interference - The objective of this subtest is to determine the effects of electromagnetic interference on the test item and subordinate or associated equipment.

#### 5.2 LIMITATIONS

a. Engineering tests of radio sets which are integral to a communication assemblage incorporating PCM multiplexers are excluded in this MTP, although the radio portion will be employed as a test transmission medium. Test procedures for a particular radio set/system are contained in the applicable MTP.

b. Engineering tests of individual special cable assemblies and components are not part of this test procedure. When so designated and/or directed, an operational PCM cable system consisting of terminal units, cable, and repeaters is considered as a test item.

c. Standard signaling and 2-wire/4-wire converter equipments employed as adjuncts to the test item are excluded.

## 6. PROCEDURES

### 6.1 PREPARATION FOR TEST

#### 6.1.1 Prescheduling Conditions

a. A latter phase of test plan organization shall include a survey of transmission facilities, operating personnel, and land areas which can be utilized for the various tests within the allocated test time frame.

b. Tests shall be performed with the test item employed in system configurations outlined in Figure 1. It is not mandatory or intended that all tests/subtests be performed on all system configurations. The selection of test elements shall be governed by (1) the test directive, (2) availability of time, materiel, and personnel, and (3) judgment of the test planner. However, it is important that all parameter tests be conducted on the test item in the closed system configuration in order to obtain basic performance data for correlation with complete system performance data. The test plan shall include a table showing the tests to be performed on each test item configuration.

c. Sufficient repetition of tests and subtests shall be specified in the test plan to produce statistically valid data with respect to the number of available test item samples. This specification shall be governed by time and facility factors and MTP 6-1-003, "Determination of Sample Size". It may be modified during conduct of the test as indicated by monitored test results.

#### 6.1.2 Pre-Testing Conditions

##### 6.1.2.1 General Preparations

General test preparation shall include:

a. Assurance checks that test facilities, equipment, and accessories are available, operational, and meet certified calibration requirements. Primary AC/DC power shall be checked to ensure correct values.

b. Inventory, assembly, and inspection of test item samples and materials.

c. Arrangements for supporting or participating agencies, activities and facilities.

d. Test personnel briefing and provision of requisite instructions,

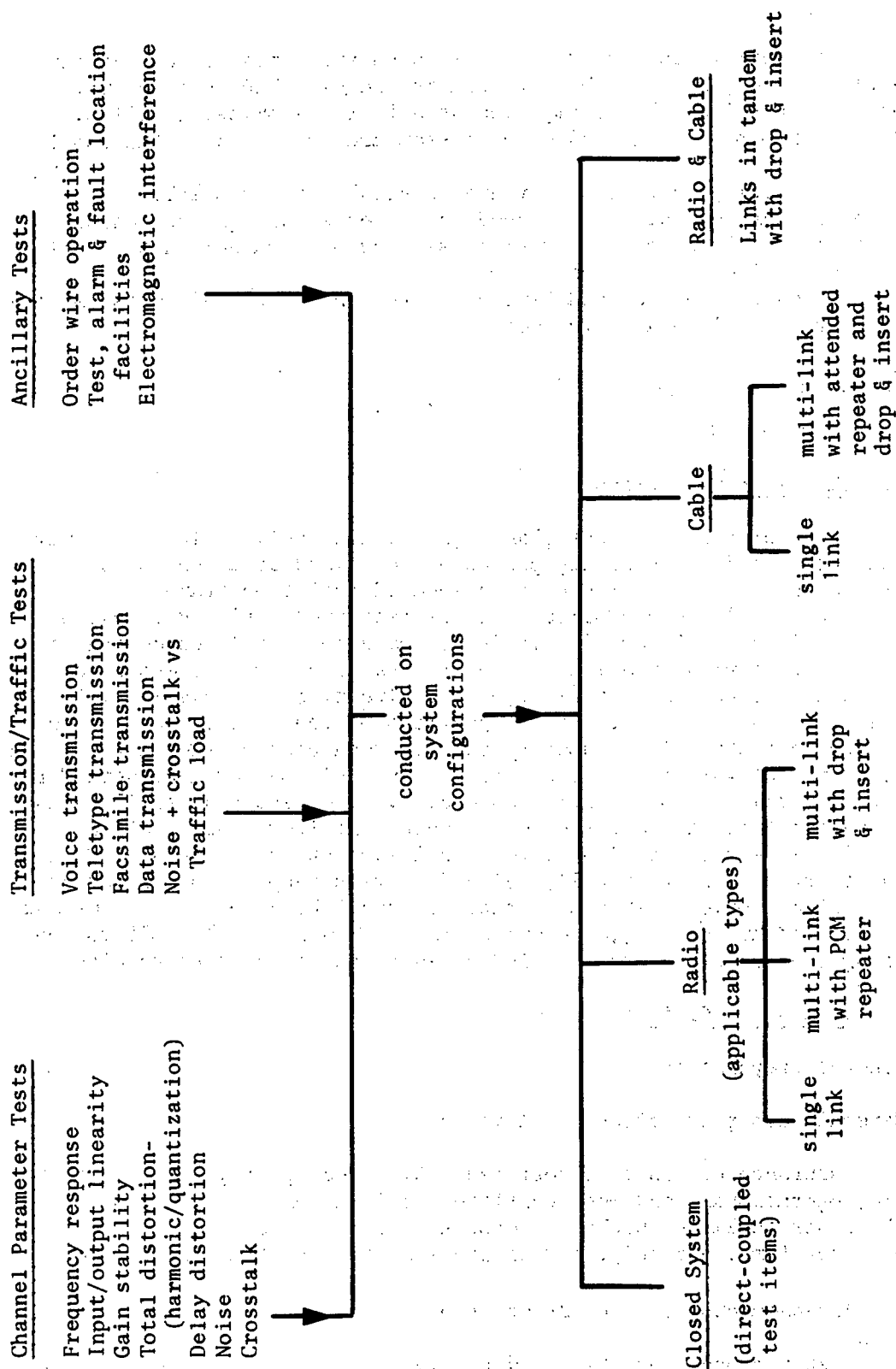


Figure 2. Engineering Test Structure for PCM Multiplexers

manuals, and data collection material.

#### 6.1.2.2 Special Preparations

Special preparations which are pertinent to specific subtests are included in the applicable Test Conduct Sections.

#### 6.1.3 Test Conditions

a. Test systems shall include but not be limited to the basic test item-transmission media configurations outlined in Figures C-1 through C-9. (See Appendix C). The systems diagrammed do not represent any specific channel capacity; the "basic unit" and "combiner" components shown represent one or more units dependent upon test item design. The test item components shall be configured to provide systems of different capacities and capabilities as indicated by the Qualitative Materiel Requirement and/or test directive, for example: 6-, 12-, 24-, 48-, or 96-channel operation.

b. Radio systems shall be the duplex, line-of-sight and/or tropo-scatter types having technical characteristics, e.g. bandwidths, compatible with the test item and in consonance with communication system concepts.

c. The cable system represented in the assemblage of cable and equipment designed for use with specific PCM multiplex equipment and when employed as the test transmission medium, shall be considered as part of the test item. Comparable cable systems may be employed when authorized.

d. Line termination/signaling converters, when required, shall not be considered part of the test item unless designed and included as a specific component.

e. In setting up the test system and the paralleling control system, maximum use should be made of the loop-back technique, i.e. placing input and output operations at a common location, thus conserving space, time, and personnel.

### 6.2 TEST CONDUCT

#### 6.2.1 Parameter Tests

The following special preparations shall be common to all parameter tests:

a. Preparation shall be made to ensure that the parameter tests are conducted in both directions on the voice-frequency (audio) channels of the test item.

NOTE: Channel input/output impedance shall be considered to be a nominal 600 ohms in the frequency band of 300 to 3500 Hz or as established by previous design/acceptance tests.

b. Choose the 4-wire channel input as the transmission level reference point. Signal power level at this point shall be -4dbm, hereinafter designated 0dbm0. Select a test tone with a frequency of 1KHz at a level of 0dbm0.

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c. Although the test setup diagrams depict, generally, basic items of test equipment, automated and combination versions shall be utilized where practicable together with chart/tape recorders for data collection in order to conserve test time.

#### 6.2.1.1 Frequency Response

- a. Arrange equipment according to Figure 2.
- b. Adjust channel gain to 0db (channel output level of 0dbm0) with the test tone input.
- c. Set signal generator successively for frequencies of 200, 250, 300, 500, 1000, 2000, 3000, and 3500 Hz with constant output of 0 dbm0 and measure received levels at channel output.
- d. Repeat the above procedure (b.) for frequencies of 60 and 3640 Hz and signal generator output of -10 dbm0.
- e. Record received levels in dbm0 at each frequency.

#### 6.2.1.2 Input-Output Linearity

- a. Arrange equipment according to Figure 2.
- b. Adjust channel gain to 0db with the test tone input.
- c. Channel output levels shall then be measured and recorded at frequencies of 300, 1000, and 3500 Hz for input (signal generator output) levels of -35, -25, -15, -5, and +10 dbm0.

#### 6.2.1.3 Gain Stability

- a. Arrange equipment according to Figure 2.
- b. Adjust test tone input and initial channel output level to 0.dbm0 (0.db gain).
- c. Monitor and record the output level in dbm0 at intervals of 4, 8, and 24 hours or continuously record the output level with a strip recorder for a 24-hour period.

#### 6.2.1.4 Distortion (harmonic and quantization)

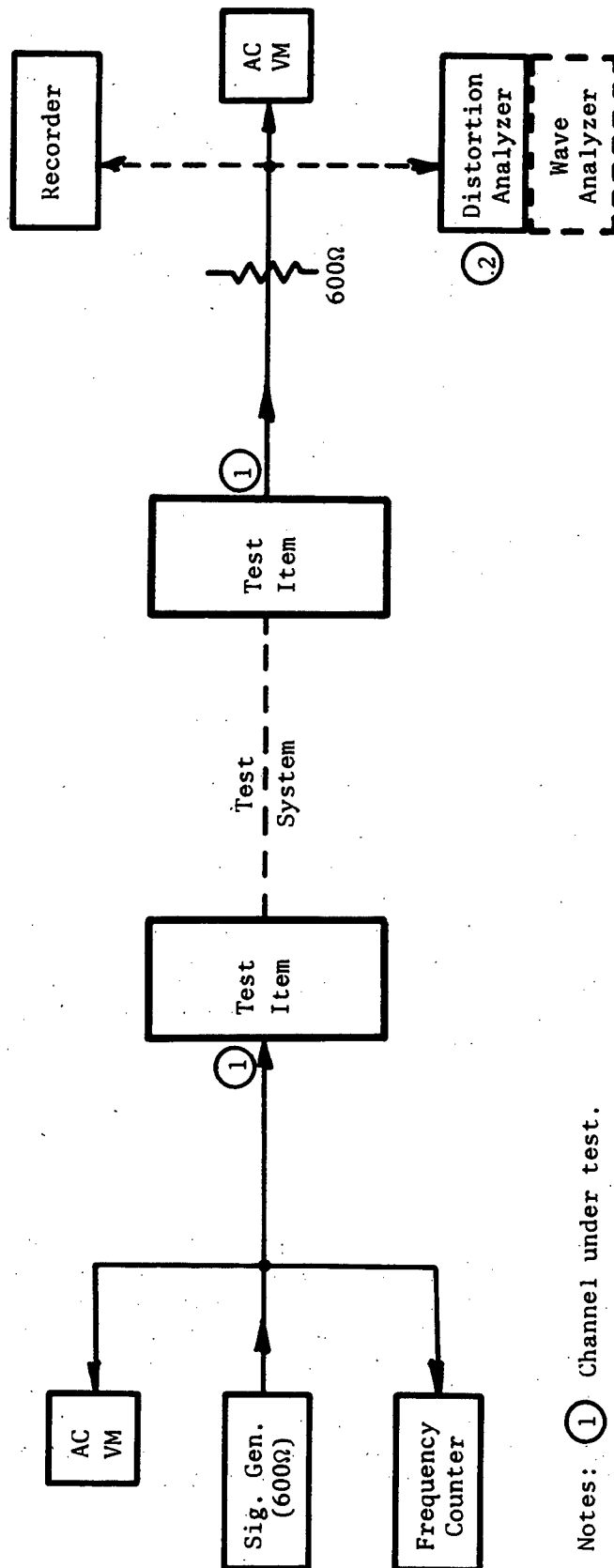
- a. Arrange equipment according to Figure 2 and substitute the distortion analyzer for the ACVM.
- b. Set the channel transmission gain to 0.db with the test tone input.
- c. With the signal generator set successively at 300, 500, 1000, 2,000, 3,000, and 3,500 Hz (and constant 0dbm0 output), measure and record the following:

- 1) Total channel output level
- 2) The "distortion only" level (fundamental suppressed).

NOTE: "Distortion only" levels in excess of specified requirements (e.g. - 30dbm0) shall be investigated with the wave analyzer to determine the causative frequency components.



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Notes: (1) Channel under test.

(2) For distortion measurement only.

Figure 2. Setup for Frequency Response, Input/Output Linearity, Gain Stability and Distortion Measurements.

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d. Record the two levels in c. above, at each test frequency and record the pertinent details of excessive distortion.

#### 6.2.1.5 Delay Distortion

- a. Arrange equipment according to Figure 3.
- b. Adjust channel gain for 0.db with test tone input.
- c. Measure and record delay in microseconds at 50 Hz increments from 300 to 3500 Hz while maintaining a constant signal generator output level of 0dbm0.

#### 6.2.1.6 Noise

- a. Arrange equipment according to Figure 4.
- b. Set channel gain to 0.db with the test tone input.
- c. Arrange the noise measuring set for transmission level measurement and measure the received 1 KHz signal (plus noise) level.
- d. Record results of measurements in c. above, in dbm.

NOTE: If noise set does not have this capability, measure the signal +noise with the ACVM.

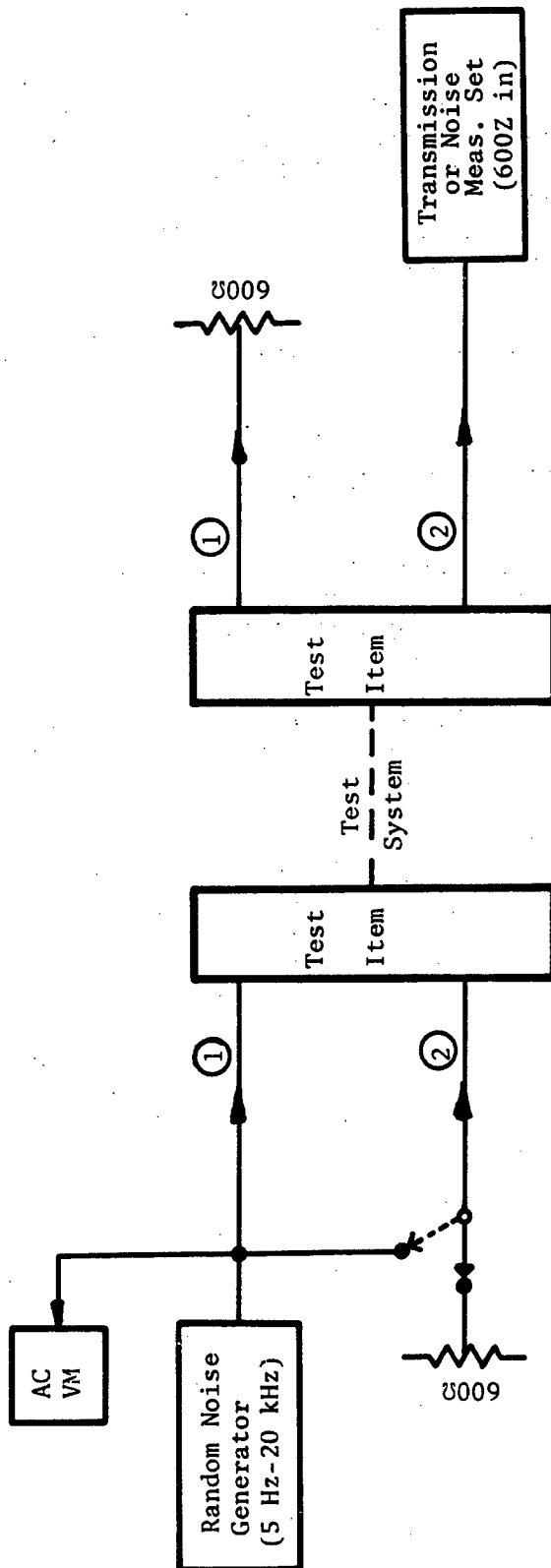
- e. Arrange measuring set for noise measurements with F1A line weighting.
- f. Disconnect the signal generator and terminate channel input in 600 ohms.
- g. Measure and record the channel noise only in dba.

NOTE: Should stated noise requirements for a certain test item specify other line weightings, e.g. C-message, the measurements shall be made with the specified weighting if the capability is provided in the test equipment. Results shall be recorded in the applicable unit, e.g. for C-message, dbrn. As an alternative, measurements made with a given line weighting may be converted to values of the required weighting as outlined in Reference 4A.

#### 6.2.1.7 Crosstalk

- a. Arrange equipment according to Figure 5.

NOTE: Crosstalk measurements shall be made for both directions of transmission. A representative schedule of channel measurement combinations is shown in Table I. Development of the schedule for a given test item will be governed principally by the system capacity (number of channels and channel groups) with emphasis on determination of adjacent channel and intergroup crosstalk. "Group" in this context is defined as the capacity of a basic test item component, e.g. 12 channels, which can be combined to form higher capacity systems. Tests for crosstalk caused by traffic loading effects are covered in paragraph 6.2.2.5.



NOTES: (1) Disturbing channel

(2) Disturbed channel

Figure 5. Basic Crosstalk Measurement Setup.

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- b. Set gain channels under test to 0.db with test tone input.
- c. Set noise generator output at 0dbm0 and measure crosstalk in accordance with Figure 5 and the channel/measurement schedule.
- d. Record measurement results in dbm0
- e. Transfer the input of channels designated "disturbed" to the noise generator, check level at 0dbm0 and measure signal + crosstalk level at the output with the transmission measuring set.
- f. Record measurements in dbm0.
- g. Repeat steps e and f above for the opposite direction of transmission.

#### 6.2.2 Transmission/Traffic Tests

The following special preparations and conditions shall be common to all Transmission/Traffic Tests:

a. Figure 6 illustrates a generalized setup to implement the subject tests. Test setup details are incorporated in the specific test procedures with references to Figure 6, however, the following general setup features are noteworthy.

- 1) The number of test item channels and the channel grouping shown are for illustrative purposes only.
- 2) The Distribution Unit shown supplies test transmissions from a single source to several channels simultaneously, incorporating impedance matching and individual output level control. Impedance of the input and each output shall be a nominal 600 ohms. Output levels shall be -10 dbm0. with a nominal input of 0 dbm simulating an average loop loss for each test channel.
- 3) With reference to Note (2) of Figure 6, the receiving/recording equipment is to be connected to only one channel at a time within each channel grouping (voice, teletype, etc.), with each of the remaining group channels terminated in 600 ohms (R2). The 10. db pad, R1, simulates a receiving loop loss.

b. Tests shall be conducted in a minimum of three steps or levels, e.g. test traffic applied to 30, 60, and 100\* per cent of total channels and repeated for opposite direction of transmission (\*less one channel for noise-crosstalk measurements). Test time at each level will be termed a test period. Test signals from all sources are to be transmitted simultaneously and continuously during the allotted test period to ensure channel loading.

c. All traffic types shall be included in each step with distribution approximately as follows:

- 1) Voice - 40% of occupied channels
- 2) Teletype - 20% of occupied channels
- 3) Facsimile - 10% of occupied channels
- 4) L. S. Data - 20% of occupied channels
- 5) H. S. Data - 10% of occupied channels (or within test item capability).

facsimile sets as shown in Figure 14. Selection of test charts and recording material shall be guided by MTP 6-2-080 "Facsimile Sets" and characteristics of the facsimile set employed.

- 1) During the first or last part of each test period (30%, 60%, 100% traffic load level) transmit and record the selected test chart at maximum machine speed. Remainder of test period is to be devoted to Part II.

c. Part II shall be instrumented by substituting a vf magnetic tape reproducer for the facsimile sending set, eliminating the recording set, and terminating all facsimile group channels. A prepared test tape of typical facsimile signals shall then be used for channel loading transmission during the remainder of the test period.

#### 6.2.2.4 Data Transmission Tests

a. Instrumentation and conduct of these tests shall be in accordance with common engineering test procedure MTP 6-2-518, "Data Transmission Tests" supplemented with the procedures below for the subject test item.

b. Military PCM multiplex systems generally provide or are being developed to provide two means of handling data communications, categorized as low speed and high speed for the purpose of this MTP.

- 1) Low speed data is defined as that which can be transmitted over a nominal 3. kHz voice channel after digital-analog conversion, the actual bit rate being dependent upon the technique employed. For this test procedure, maximum low speed data transmission rate is considered as 2400 bits/second.
- 2) For this procedure high speed data is defined as information in dc digital form at rates on the order of 48,000 bits/second.

NOTE: A method of high speed data transmission incorporated in the design of the type PCM-TDM system under consideration involves bypassing the input circuitry of a voice channel and injecting the digital data, "n" bits at a time, into the pulse train time slots normally occupied by the vacated voice channel. ("n" = normal number of bits per channel time slot of the given PCM-TDM system). Retrieval at the distant terminal is accomplished by a reverse process. Special interface equipment is required between the data equipment and the PCM terminals; synchronization is supplied by the latter. The test item design may provide for several high speed data channels for use as required but at the sacrifice of an equivalent number of voice channels.

c. With reference to Figure 6 and MTP 6-2-518, low speed data in analog form shall be transmitted and recorded in the established test periods.

d. On the assumption that the test item incorporates direct high speed digital data channel capabilities, the setup shown in Figure 14 shall be used and the same procedure followed as for low speed data transmission except for transmission speed and signal level which shall be commensurate with the test item and interface equipment.

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#### 6.2.2.5 Noise and Crosstalk versus System Loading

a. Noise-plus-crosstalk measurements shall be made on the monitor channel (reference Figure 6) at least once during each test period (traffic load level).

b. Measurements shall be made and recorded in accordance with paragraphs 6.2.1 and 6.2.1.7.

#### 6.2.3 Ancillary Tests

##### 6.2.3.1 Order Wire Operation

a. No specific test procedure is prescribed for this facility since it is utilized throughout the majority of tests.

b. The order wire channel shall be checked for the capability to provide satisfactory communication between all attended stations of a system comprised of any combination of radio and cable links. Specific characteristics to be observed, measured if deficient, and reported on are as follows:

- 1) Audio level and quality
- 2) Signaling
- 3) Noise
- 4) Crosstalk to or from system channels
- 5) Undesirable operating features or conditions.

##### 6.2.3.2 Integral Test Facilities

a. These facilities will be used throughout the test series in accordance with the procedures set forth in the specific test item instruction manual. Data for determination of their adequacy and reliability shall be derived from operator's logs and the test engineer's notes and made an item of test data at least once during each test system series.

b. Alarm and fault location features shall be tested in accordance with References 4.P, 4.Q, 4.R, and the test item design.

##### 6.2.3.3 Electromagnetic Interference (RFI) Tests

Tests for electromagnetic interference (radiated/conducted emission and susceptibility) shall be conducted in accordance with the applicable sections of Reference 4.C. and the provisions outlined herein.

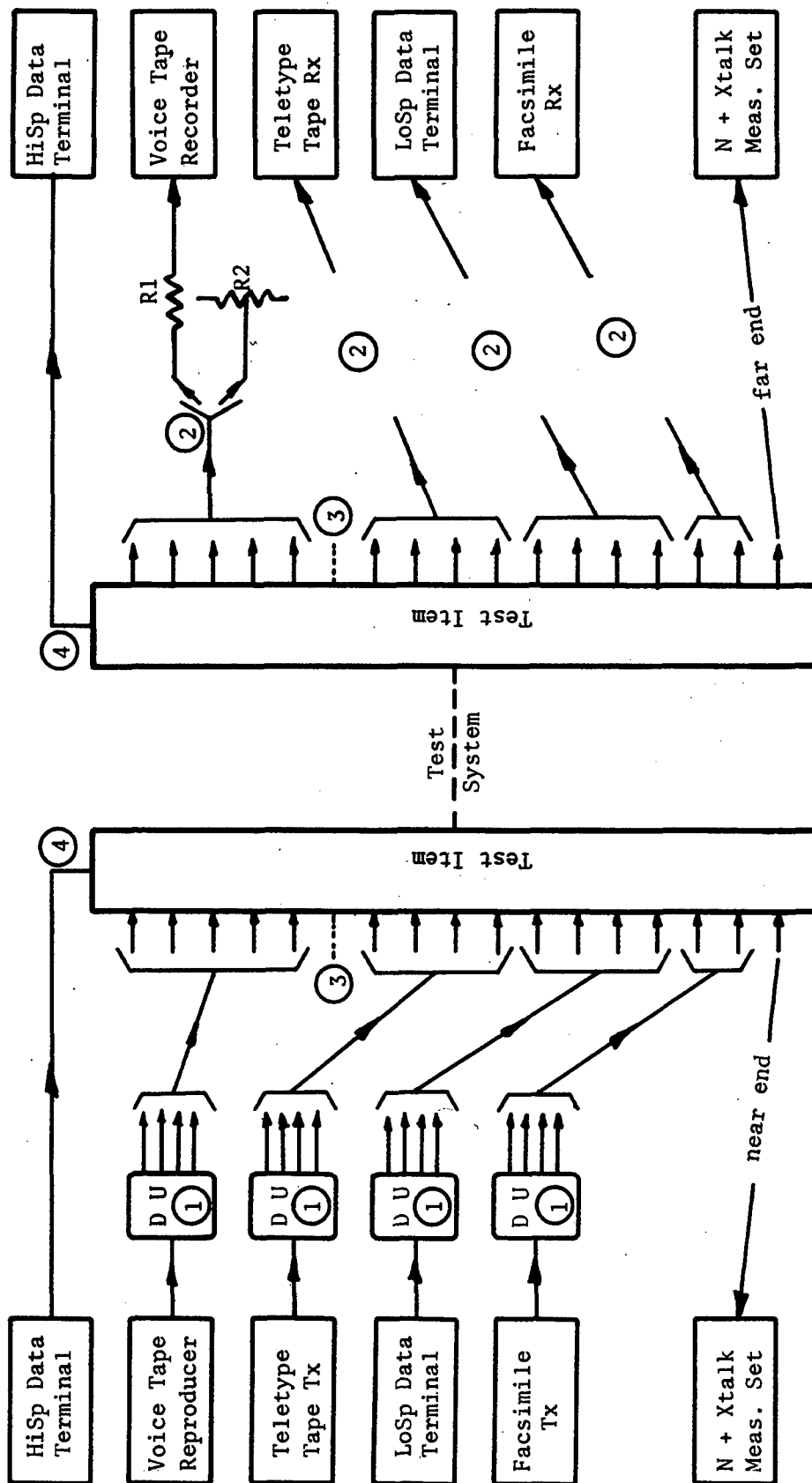
a. Terminal components shall be tested in the closed system configuration in the prescribed controlled environment (screen room).

b. Open field tests shall be conducted with the test item in an operational system configuration.

c. A representative portion of the operational cable system shall be subjected to the interference tests and shall include a minimum of one unattended repeater (pulse restorer). Tests shall be conducted on both surface and aerial types of cable installation.

d. The narrowband emission tests should be focused on test item pulse train fundamental frequency, e.g. 2304 kHz.

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- Notes:
- ① — Distribution Unit- see par. 6.2.2.1 b.(2).
  - ② — Selected channel recorded; remainder terminated. R1=10.db pad. R2=600 ohms.
  - ③ — Voice channel vacated for ④
  - ④ — Pulse train data channel.

Figure 6.. Generalized Setup for Transmission/Traffic Tests.

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d. The test item system shall be aligned and all channels adjusted to 0.db gain prior to each test period and checked at appropriate intervals.

#### 6.2.2.1 Voice Transmission

a. This test shall employ the articulation testing techniques described in Appendix C.

b. The tape-recorded list of phonetically-balanced (PB) words shall be transmitted and recorded via the selected channels a sufficient number of times to ensure valid test data. (Reference Figure 6). The number of voice group channels to be recorded is at the discretion of the test planner/engineer; a minimum of one-third is recommended.

c. Repeat the above procedure for the 30%, 60%, and 100% levels of channel occupancy and for the opposite direction of transmission.

#### 6.2.2.2 Teletype Transmission Test

a. The teletype test signal source and recording equipments shall consist of standard single-channel or multi-channel (FDM) teletypewriter equipments dependent upon availability and comparable considerations. Primary requirements are for voice-frequency teletype line signals of maximum waveform complexity at maximum transmission speeds.

NOTE: An alternative measure may be employed whereby vf signals produced by standard equipments are recorded on magnetic tape which can then be used in the same manner as the Voice Transmission Test. It is important that the original test messages in page copy or punched tape form be retained for use in final test data reduction.

b. Test messages shall be pre-punched on standard tape and consist of non-redundant clear text or 5-letter code groups. Length should be a minimum of 10,000 characters and include suitable test identification, "start-of-message" and "end-of-message" entries. Tapes should be looped to provide continuous transmission during the test period by means of standard teletypewriter tape transmitter(s).

c. Recording shall be accomplished in accordance with paragraph 6.2.2.A.(3) by means of a receiving page printer or, preferably, a typing-reperforator set producing printed and punched tape. Recording equipment includes ancillary converters or demultiplexing units.

d. The above procedure shall be repeated for the 30%, 60%, and 100% levels.

#### 6.2.2.3 Facsimile Transmission Test

a. Since it is impractical to continuously transmit/record facsimile material in the test periods established for the other communication modes, this test is divided into two complementary parts: (1) determination of facsimile quality and (2) provision of continuous facsimile signals for channel loading.

b. Part I tests shall be instrumented with standard AM or FM



e. Test item susceptibility to controlled interference shall be determined by continuous monitoring of the PCM signal characteristics, checking system operating parameters with the integral test facility, and by channel quality tests.

### 6.3 TEST DATA

a. All test data, in any form, shall be properly identified with the following minimum information:

- 1) Test or subtest number and title
- 2) Nomenclature and serial numbers of test item components
- 3) Date and time
- 4) Any other information pertinent to test data correlation.

b. Data collection forms, identification labels, and photographs shall include information of the following types as indicated:

- 1) Parameter values established for the particular test, e.g. test signal level, frequency.
- 2) Test location and any unique existing conditions, including weather
- 3) Test interval (elapsed time).
- 4) Test equipment employed and/or reference to a supporting test setup diagram.
- 5) Explanatory notes.

#### 6.3.1 Parameter Test Data

##### 6.3.1.1 Frequency Response

Frequency response data in tabular form shall consist of the received signal levels measured at each frequency for the channels tested. Input level change for the 60 and 3640 Hz frequencies must be noted.

##### 6.3.1.2 Input-Output Linearity

Input-output linearity data shall be recorded in tabular form for each channel tested, entering the signal level in dbm0 received for each input level at each test frequency.

##### 6.3.1.3 Gain Stability

Gain stability test data shall consist of a data collection form showing the channel numbers and the measured output levels in dbm0 at the prescribed time intervals or an annotated and calibrated chart produced by the strip recorder.

##### 6.3.1.4 Distortion

Total distortion test data shall be recorded in tabular form showing

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for each channel and at each test frequency, the measured signal plus-distortion level and the measured "distortion only" level, both in dbm0.

#### 6.3.1.5 Delay Distortion

Delay distortion test data shall be recorded in tabular form showing the delay, in microseconds, measured at the incremental test frequencies for each channel tested.

#### 6.3.1.6 Noise

Noise test data consisting of the measured "signal-plus-noise" level (dbm0) and "noise only" level (dba or dbrn) in tabular form for each channel tested. Data must include the line weighting and specific type of noise measuring set employed.

#### 6.3.1.7 Crosstalk

Crosstalk test data shall consist of a table of channel/measurement combinations (table I) and a cross-referenced data collection form. For each combination, the measured crosstalk and the signal-plus-crosstalk levels (dbm0) shall be recorded on the data collection form.

### 6.3.2 Transmission/Traffic Test Data

#### 6.3.2.1 General

Since data derived from these tests will be in different forms and require different reduction treatment, emphasis must be placed on thorough correlation of the raw data. For each subtest listed below, the test data package will consist of the results of each test period (traffic load level) accompanied by the original test signal material and applicable operator's logs.

#### 6.3.2.2 Voice Transmission

Voice transmission test data shall consist of the magnetic tape recordings of the PB word list.

#### 6.3.2.3 Teletype Transmission

Teletype transmission test data shall consist of the received teletype tape, page copy or magnetic tape dependent upon the method employed.

#### 6.3.2.4 Facsimile Transmission

Facsimile transmission test data shall be the record copy derived in each test period.

#### 6.3.2.5 Data Transmission

Data transmission test results shall be in the forms described in

MTP 6-2-518 and as dictated by the type of instrumentation.

#### 6.3.2.6 Noise and Crosstalk

Noise and crosstalk versus system loading test data derived from the monitor channel measurements in each test period shall be recorded as described in paragraphs 6.3.1.6 and 6.3.1.7 (excluding Table I) or on a comparable combined form.

#### 6.3.3 Ancillary Test Data

##### 6.3.3.1 Order Wire Operation

Order wire operation test data shall generally be in narrative form with extracts from operator's logs and tabulated order wire transmission and signaling measurements.

##### 6.3.3.2 Integral Test

Integral test, alarm and fault location facility test data shall be recorded in tabular form listing the various functions with the respective procedure, measurements and comments.

##### 6.3.3.3 Electromagnetic Interferences

Electromagnetic interference test data shall consist of the measurement data and descriptive diagram of the test setup for each phase as described in paragraph 6.2.3.3 and in accordance with Reference 4.C.

#### 6.4 DATA REDUCTION AND PRESENTATION

##### 6.4.1 Parameter Tests

##### 6.4.1.1 Frequency Response

Frequency Response data shall be reduced to a graph showing mean deviation (y axis) from the transmission level reference versus frequency (x axis). (Transmission level reference = 0 dbm0 at 1 kHz) Channel data having maximum excursion from the mean shall be shown by a dashed curve annotated with the percentage of tested channels.

##### 6.4.1.2 Input-Output Linearity

Input-output linearity data shall be reduced to a graph of average output level (y axis) versus input level (x axis) at the test frequencies. In addition to the three frequency curves, the theoretical gain linearity shall be shown as a straight line.

##### 6.4.1.3 Gain Stability

Gain stability data shall be reduced to a graph of output level versus

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time. Output level shall be plotted on the y axis as the deviation from 0 dbm0 during the 24-hour test period shown in hourly increments on the x axis.

#### 6.4.1.4 Distortion

Total distortion data shall be reduced by computing the signal-to-distortion ratio (db) at the test frequencies and presenting the results in graphic form. An analysis of excessive distortion shall be presented in graphic, tabular, and/or narrative form to aid in evaluation and corrective action.

#### 6.4.1.5 Delay Distortion

Delay distortion data shall be reduced and presented in graphic form showing the delay times ( sec) at the test frequencies, normalized to the 1 kHz delay.

#### 6.4.1.6 Noise

Noise test data shall be reduced by computing the signal-plus-noise to noise ratio and presenting it in tabular form by channel. Dependent upon the measuring equipment employed and the specified line weighting, conversion of test data to a common noise measurement unit is required as follows:

- a. For noise measured in dba, F1A line weighting, and test signal measured in dbm, a 1000 Hz test signal of 0. dbm = 85 dba (or -85 dbm = 0.dba).
- b. For noise measured in dbrn, C-message weighting, a 1000 Hz test signal of 0. dbm = 90 dbrn (or -90. dbm = 0. dbrn).
- c. The signal-to-noise ratio is therefore the difference in db between the signal and noise levels.

#### 6.4.1.7 Crosstalk

Crosstalk test data shall be reduced by computing the signal-plus-crosstalk to crosstalk ratio (db) for each channel combination and presenting the results in tabular form.

### 6.4.2 Transmission/Traffic Tests

#### 6.4.2.1 General

The data resulting from these tests shall be reduced for each type of transmission as outlined herein, grouped by test periods (traffic load levels), and presented in composite form for each test system involved. A sample composite data from is illustrated in Figure 7. The final data may also be presented in additional arrangements for comparative analyses of certain features or characteristics.

#### 6.4.2.2 Voice Transmission

Voice transmission test data shall be reduced by direct comparison of the recorded PB words with the standard list by a qualified listener and the

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Test System _____					
Traffic Type	% of Channels in Load Level	Performance Measure	Traffic Load Level (1)		
			30%	60%	100%
Voice		Articulation Score			
Teletype		% correct characters			
Facsimile		<u>Satisfactory/</u> <u>Unsatisfactory</u>			
Data -					
Lo Sp		) Error Rate (			
		)			
		) & (			
		)			
Hi Sp		) MEFI (2) (			
Noise + Crosstalk		S/N + Xt (db)			

(1) Per cent channel occupancy

(2) Mean Error-Free Interval or equivalent

Figure 7. Sample Form for Transmission/Traffic Test Results.

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percentage of correctly understood words recorded as the Articulation Score.

#### 6.4.2.3 Teletype Transmission

a. Teletype transmission test data shall be reduced by methods dictated by the type of receiving equipment and techniques employed. "Off-line" data reduction is accomplished preferably by semi-automated techniques wherein the test signal tape and the received tape are "read" simultaneously by two synchronized teletype transmitter-distributors (tape readers). The tape reader outputs are compared in an electronic comparator which detects character errors in the received tape and a counter accumulates the number of errors. An auxiliary counter may be employed to count total characters.

b. Irrespective of data reduction method (manual or automatic), the percentage of correct characters received shall be recorded (Figure 7) as the measure of transmission quality.

#### 6.4.2.4 Facsimile Transmission

Facsimile transmission test data reduction shall be accomplished by direct visual comparison of the subject and record copies. Parameters for comparison will be dependent upon the type of subject copy. Reference is made to MTP 6-2-080 Facsimile Sets, for details. For the purpose of this procedure, the record copy shall be graded as satisfactory or unsatisfactory supported by a brief description of unsatisfactory results.

#### 6.4.2.5 Data Transmission

Data transmission test data reduction shall be accomplished as described in MTP 6-2-518, Data Transmission Tests for both low-speed and high-speed types. The resultant performance data shall be recorded as the overall bit or character error rate and the mean error free interval expressed in bits or characters.

#### 6.4.2.6 Noise and Crosstalk

Noise and crosstalk versus system loading test data shall be reduced by computation to the ratio in db of the noise-plus-crosstalk measured at each load level to the normal 4-wire receive signal level (-4 dbm). Results shall be presented in accordance with paragraph 6.4.2.1.

#### 6.4.3 Ancillary Tests

##### 6.4.3.1 Order Wire

Order wire operation test results shall be compiled and presented generally in narrative form emphasizing adequacy, reliability, and facility of operation and including the parameter data listed in paragraph 6.2.3.1.

##### 6.4.3.2 Integral Service Facilities

Integral service facilities test results shall be compiled and

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presented as described in paragraph 6.3.3.2. Noted deficiencies and shortcomings shall be described in sufficient detail, including recommendations, to permit evaluation for potential corrective action.

#### 6.4.3.3 Electromagnetic Interference

a. Test results shall be compiled and presented in the following form for each subtest:

- 1) Narrative description of the subtest including test conditions.
- 2) Detailed diagram of the test setup with special attention to actual spatial relationship of test items and test equipment.
- 3) Measurement data in tabular and/or graphic form.

b. Presentation of test results shall be in consonance with the military standards (References 4.B, C., and D.) and the provisions of paragraph 6.2.3.3. Approved deviations from or modification of the military standard requirements/procedures shall be described.

## APPENDIX A

### TDM - PCM MULTIPLEXING

A. Time-division multiplexing requires some form of pulse modulation or, contextually, analog-digital conversion. There are several varieties of pulse modulation which are capable of representing analog signal samples. Examples of PM methods include the techniques of varying, within the assigned time interval, the pulse amplitude (PAM), pulse width (PWM), pulse position (PPM), number of pulses (PNM), or by a coded arrangement of pulses (PCM). The latter method, PCM, has been generally accepted as being the most advantageous, though at the expense of some increase in carrier bandwidth due to the increased number of pulses required. In the PCM method the time interval assigned to each channel sample is divided into a constant number of pulse "spaces" (e.g. six). The presence or absence of a pulse in the spaces represent the digits, "1" or "0" respectively of a binary number which is indicative of a signal sample condition. The pulses are of constant amplitude and width, thus the receiving decoder has only to detect the presence or absence of pulses.

B. The combination of pulse-code-modulation and time-division-multiplexing processes forming a generic multi-channel communication system is summarized in the following paragraphs. Figure 1 depicts one half of a simplified system and the signal conversions involved.

(1) Sampling. The signals of several voice frequency channels are sequentially sampled at a rate at least twice the highest voice frequency in order to retain usable intelligence. Each sample becomes a signal pulse whose amplitude is equivalent to that of the signal at the instant of sampling. This stage of the process is actually PAM.

(2) Quantizing. Amplitude of the PAM samples is measured against a quantized scale of a given number of parts or levels. Each level and therefore, any matching signal sample is identified by a binary number.

(3) Coding. Each PAM sample is then coded according to its amplitude to become a series of pulses/no pulses or bits (binary digits) representing its binary number. The number of digits (bits) per word is constant for a given system and is a function of the number of levels of the quantized scale in binary notation.

(4) Transmission. The coded samples or words are then applied to the transmission medium in channel sequence, the total samples of one scan constituting a "frame".

(5) Reception. The pulse train is received at the distant terminal where it is retimed and reshaped and each word decoded to its equivalent level. These signal levels are distributed to (de-multiplexed) their appropriate receiving voice channels where they are accumulated, thus reproducing the original signals.



(6) Synchronization is accomplished by (1) inserting an address signal into the pulse train at frame intervals, (2) detecting it at the receiving terminal, and (3) adjusting receiver timing to agree with transmitter timing.

(7) Data Transmission Considerations. Low and medium speed DC digital data may be transmitted via a voice frequency channel of a PCM-TDM system by first converting the data pulses to quasi-analog form (in the same manner as for DC teletypewriter signals) and reconvert them beyond the far terminal. High-speed digital data may be transmitted without signal conversion in some PCM-TDM systems by bypassing a channel input circuitry and injecting the data pulses, "N" bits at a time, directly into the pulse train in the time slot assigned to the vacated voice channel. "Metering" of the data pulses is accomplished by synchronizing the data interface equipment with the PCM-TDM system timing. At the receiving terminal, the bursts of data pulses are extracted from the pulse train, recoupled in time by the data interface equipment to form the original data bit stream, and routed to the data user.

C. Throughout this summary of PCM-TDM processes, only one direction of transmission has been discussed. However, an operational system includes an identical set of components, facilities, and functions operating in the opposite direction although the transmitting and receiving elements of each terminal are combined physically and share common functions such as timing. In other words, the system is full duplex including channel input/outputs and the transmission medium.

D. For operational flexibility, the capacity of military systems may range from 6 to 96 or more channels with the major components designed on the "building block" principle, thus providing the means of implementing communication links of low, medium, or high traffic capacity. Military PCM-TDM systems as a rule do not have integral channel signaling features or 2-wire/4-wire conversion capability. These features are usually incorporated in a separate multi-channel converter unit employed at the system terminals with various options available for any channel.

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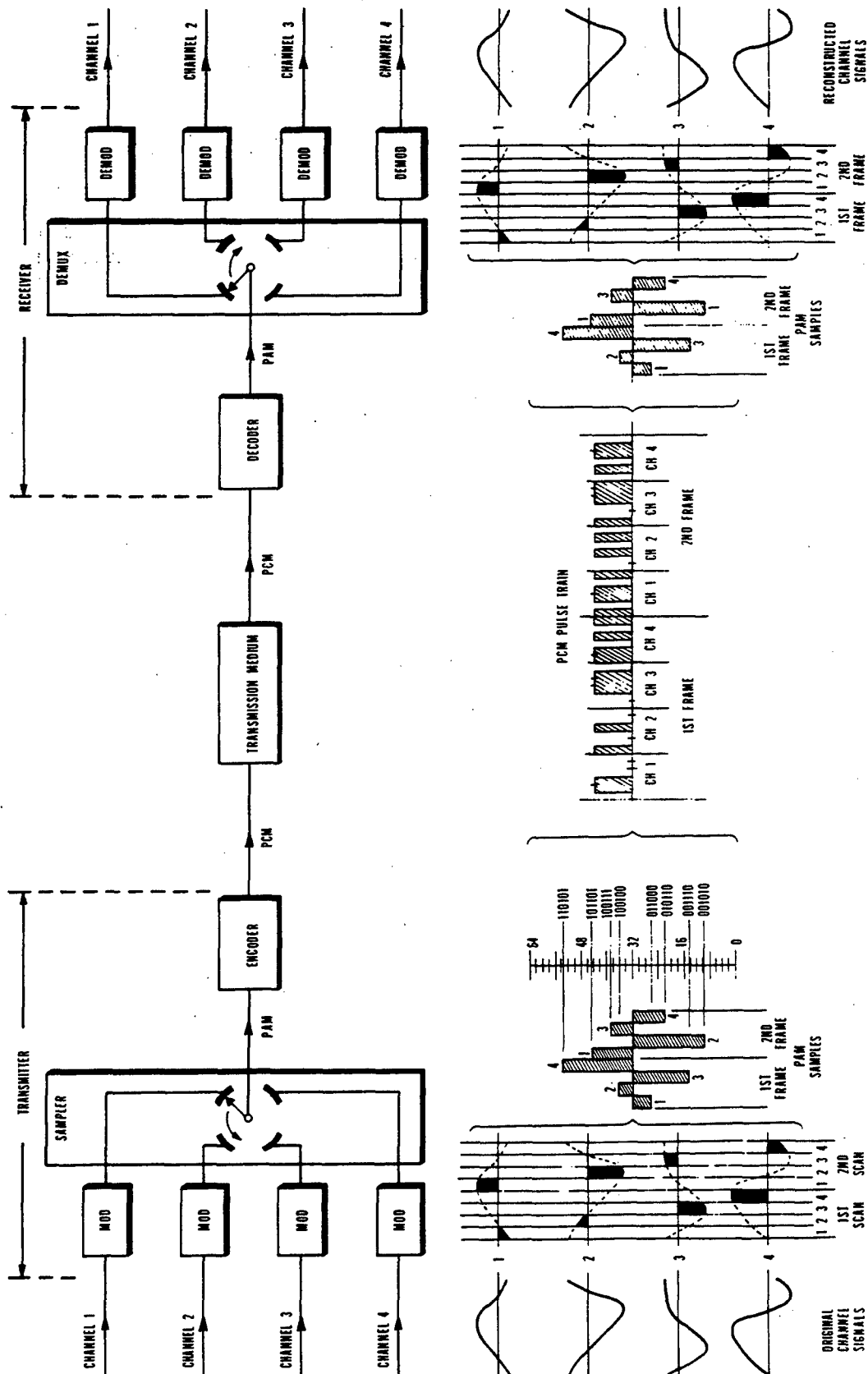


Figure A-1. Elements and Signal Forms of a Generalized PCM-TDM System [one direction shown]

## APPENDIX B

### ARTICULATION TESTING

A. Various organizations and individuals have evolved a methodology for evaluating the "intelligibility" characteristic of a voice communication system which has come to be known as articulation testing. Intelligibility in this context is operationally defined as being the number of words correctly identified by a qualified listener from a list of 100 words whose phonetic characteristics are representative of the distribution of phonemes in the English language. The result is known as the articulation score (AS).

B. For direct testing, the talker pronounces phonetically balanced (PB) words chosen from a prepared list (see attached) into the end instrument microphone, maintaining a relatively constant speech level by monitoring a VU meter connected to the circuit. When spoken, each of the PB words is prefaced with a phrase such as, "You will write \_\_\_\_\_". The listener(s) at the receiving end instrument marks the words on an identical form as he understands them. The received list is then scored as described above. A representative list of PB words commonly employed in articulation testing is given below.

C. In order to expedite the process and also permit repetition without variation of test signals under the different system traffic conditions, the spoken words may be recorded on magnetic tape and reproduced through the system under test to a comparable recorder. The received recordings can then be scored during convenient post-test periods. Emphasis must be placed on the use of high quality recorder-reproducer equipment and material to reduce the introduction of adverse effects.

D. References may be consulted for additional PB word lists and a more exhaustive treatise on the principles of articulation testing. Reference is also made to MTP 6-2-509, Electromagnetic Compatibility Tests and MTP 6-2-508, Electromagnetic Vulnerability Tests which contain the description and use of an automated intelligibility measurement system known as the Voice Interference Analysis System (VIAS). If available and authorized, this system can be used in lieu of the method described above.

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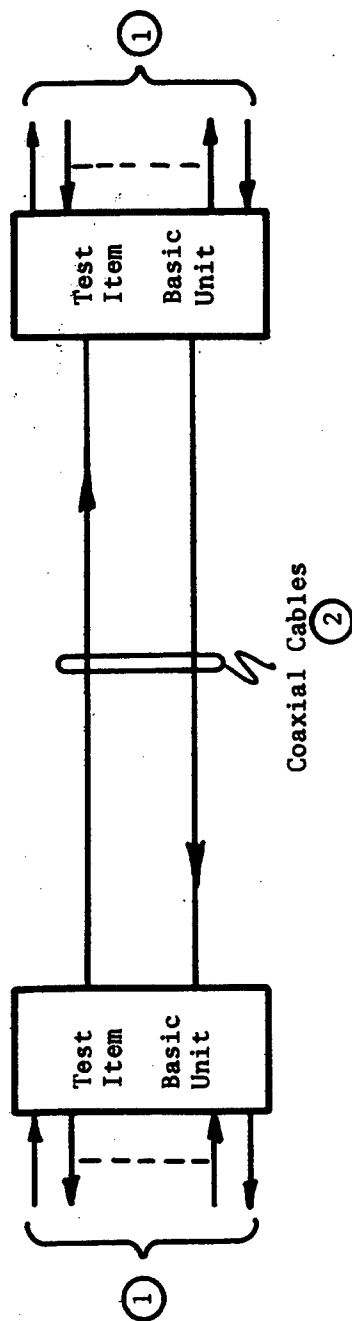
# Representative Phonetically Balanced (PB) Word List

1	lick pick tick wick sick kick	14	sad sass sag sat sap sack	27	sung sup sun sud sum sub	40	cave cane came cape cake case
2	seat meat beat heat neat feat	15	sip sing sick sin sill sit	28	red wed shed bed led fed	41	game tame name fame same came
3	pus pup pun puff puck pub	16	sold told hold cold gold fold	29	hot got not tot lot pot	42	oil foil toil boil soil coil
4	look hook cook book took shook	17	buck but bun bus buff bug	30	dud dub dun dug dung duck	43	fin fit fig fizz fill fib
5	tip lip rip dip sip hip	18	lake lace lame lane lay late	31	pip pit pick pig pill pin	44	cut cub cuff cuss cud cup
6	rate rave raze race ray rake	19	gun run nun fun sun bun	32	seem seethe seep seen seed seek	45	feel eel reel heel peel keel
7	bang rang sang gang hang fang	20	rust dust just must bust gust	33	day say way may gay pay	46	dark lark bark park mark hark
8	hill till bill fill kill will	21	pan path pad pass pat pack	34	rest best test nest vest west	47	heap heat heave hear heath heal
9	mat man mad mass math map	22	dim dig dill did din dip	35	pane pay pave pale pace page	48	men then hen ten pen den
10	tale pale male bale gale sale	23	wit fit kit bit sit hit	36	bat bad back bath ban bass	49	raw paw law saw thaw jaw
11	sake sale save same safe sane	24	din tin pin sin win fin	37	cop top mop pop shop hop	50	bead beat bean beach beam beak
12	peat peak peace peas peal peach	25	teal teach team tease teak tear	38	fig pig rig dig wig big		
13	king kit kill kin kid kick	26	tent bent went sent rent dent	39	tap tack tang tab tan tam		

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## APPENDIX C

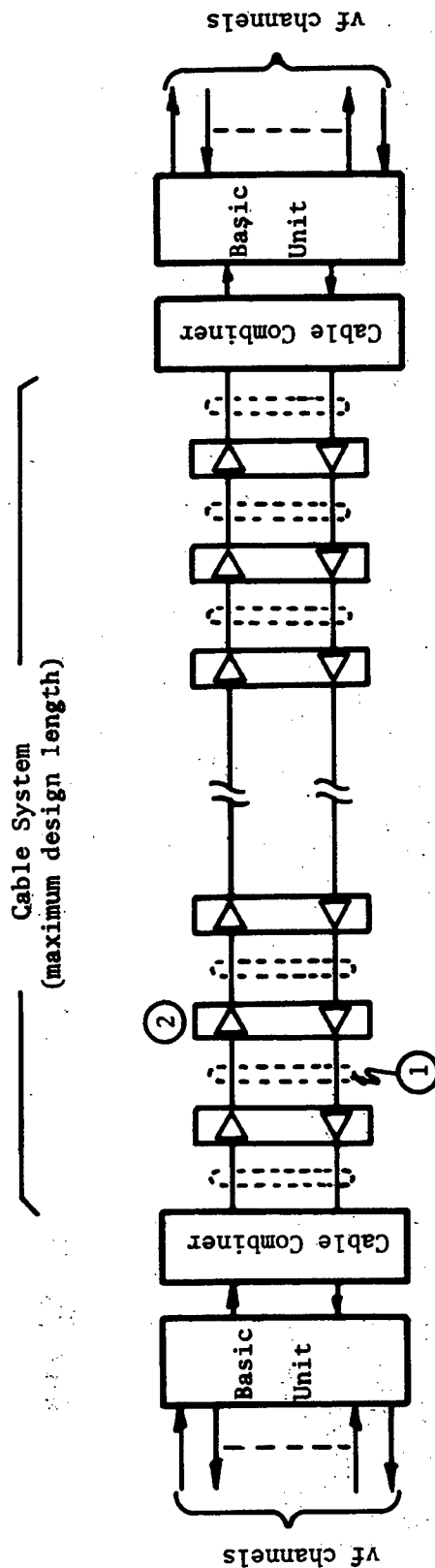
### SYSTEM CONFIGURATIONS



Notes: (1) 4-wire audio channels to test equipment, 4-wire end instruments, or 2-wire end instruments through converter.

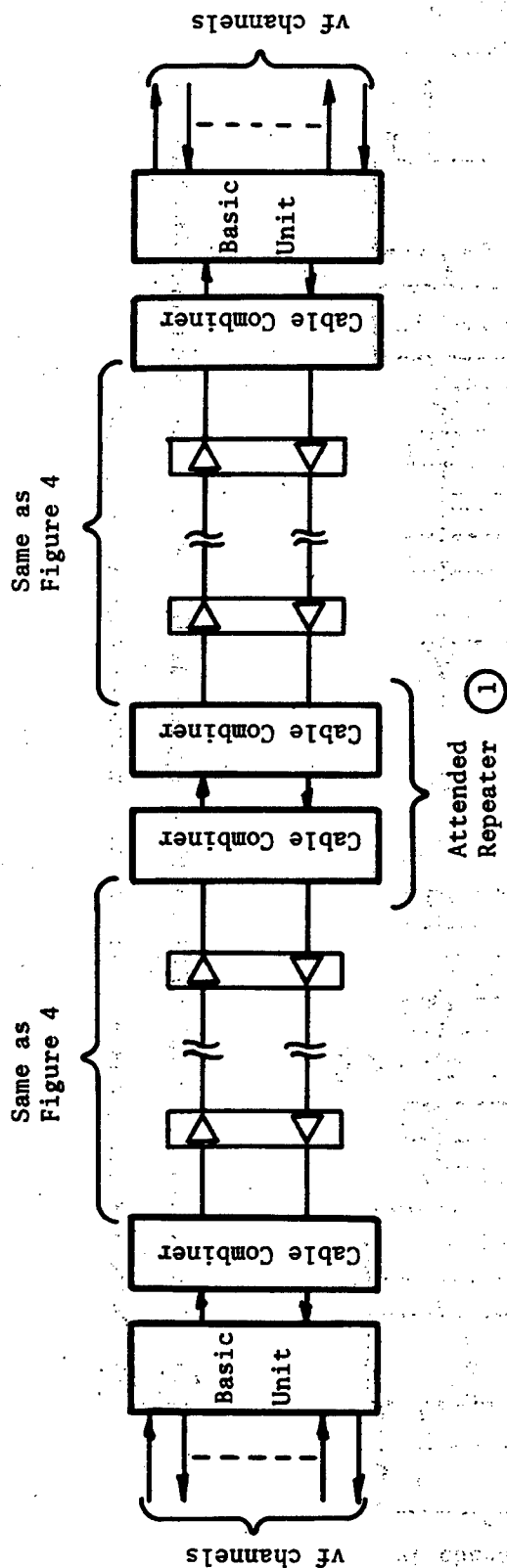
(2) Sufficient length to interconnect units within test room. Cable  $Z_0$  test item  $Z_0$ .

Figure C-1. Closed System Test Configuration



- Notes:
- ① Shielded twin coaxial cable section; system design length. All sections identical.
  - ② Pulse restorer; one each cable section junction or as indicated.

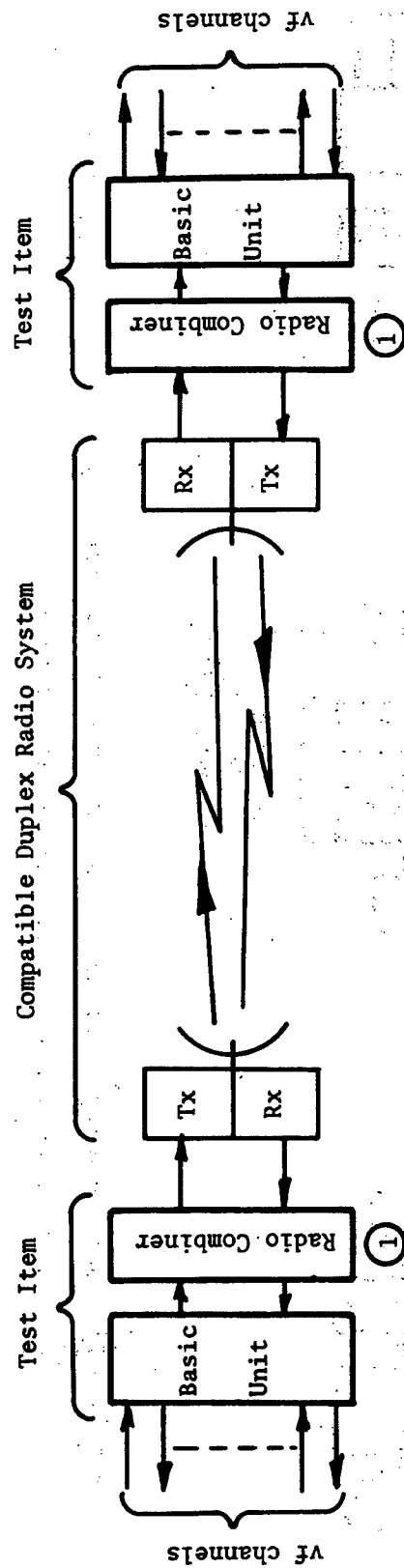
Figure C-2. Cable System Application-Repeater Not Required



Note ① May include drop/insert facility - see Figure 9.

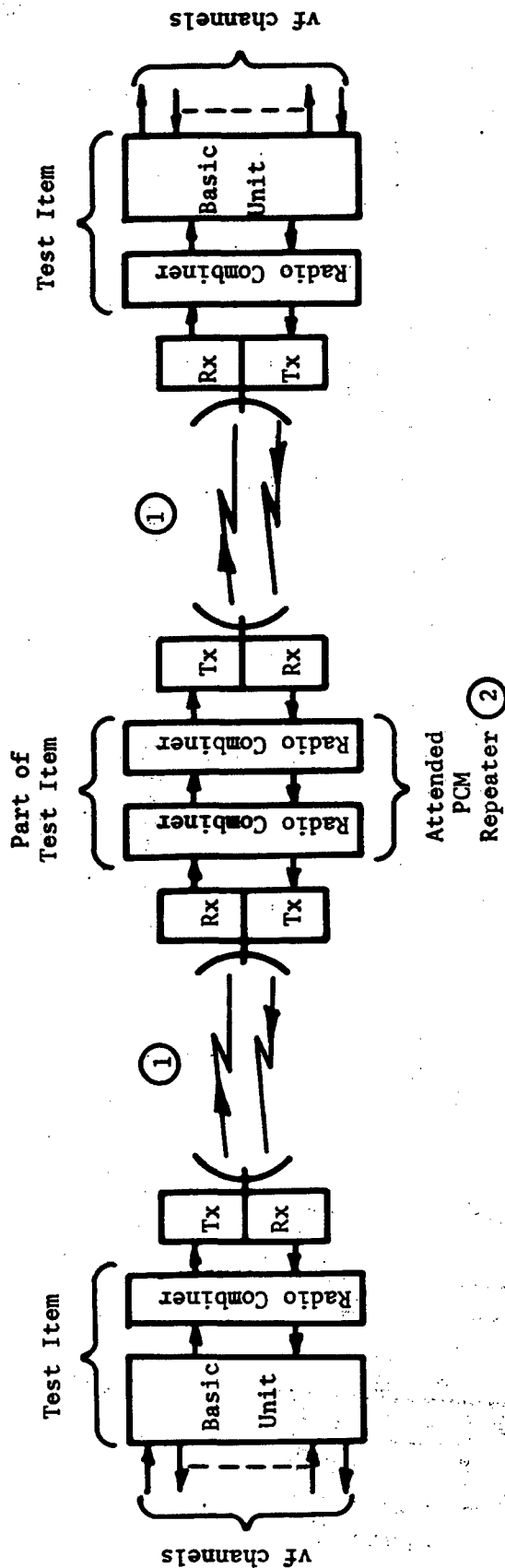
Figure C-3. Cable System Application - with Attended Repeater





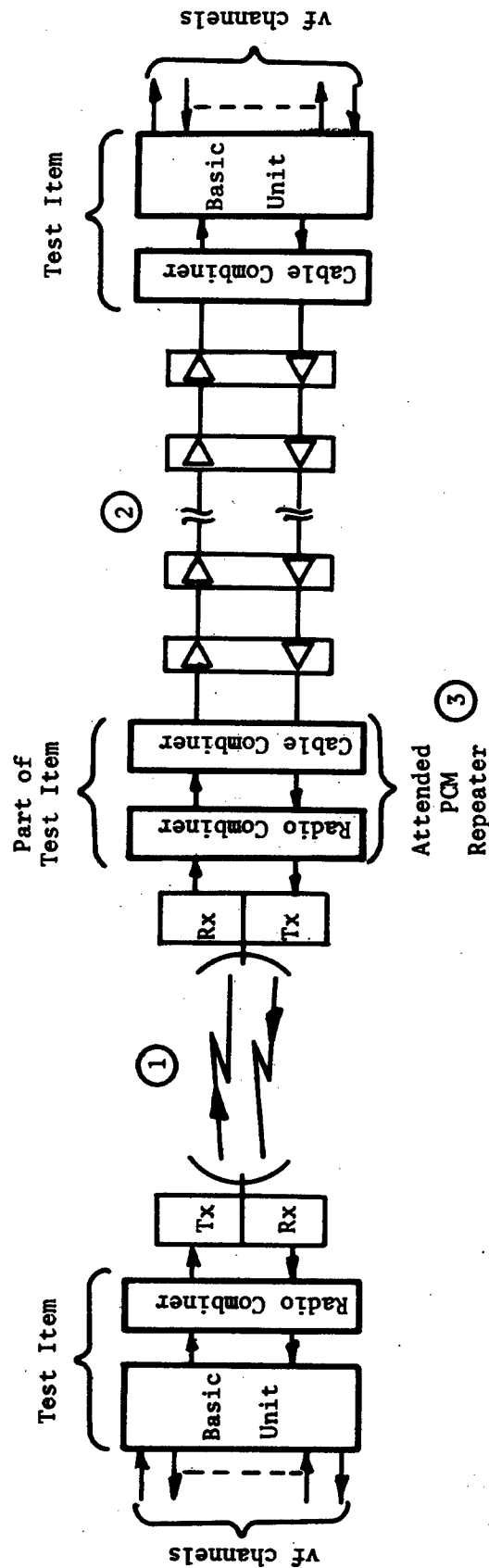
Note ① Not required with certain radio sets in low capacity systems.

Figure C-4. Radio System Application - PCM Repeater Not Required



- Notes:
- (1) Compatible duplex radio systems; not necessarily same type.
  - (2) May include drop/insert facility - see Figure 9.

Figure C-5. Radio Systems in Tandem - PCM Repeater Required



- Notes: (1) Radio system as in Figure 7.  
(2) Cable system as in Figure 4.  
(3) May include drop/insert facility - see Figure 9.

Figure C-6 Integrated Radio/Cable System Application.

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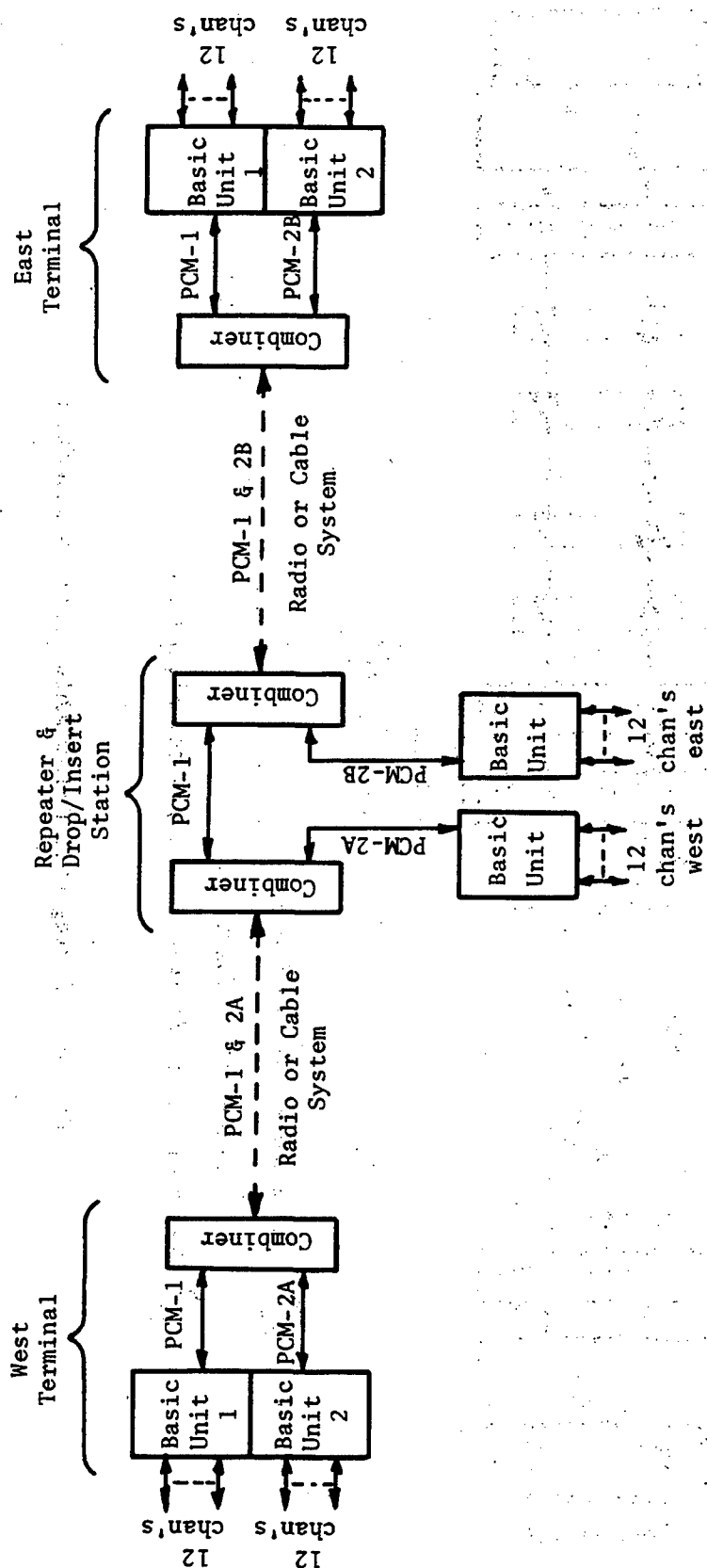


Figure C-7. Simplified Diagram of Basic Drop and Insert Application (24-channel system shown)